USC Viterbi School of Engineering

CSci551/651: Advanced Computer Networking

Units: 4.0

FA2025— Monday/Wednesday— 10am–11:50am

Instructor: John Heidemann

Contact info: johnh@isi.edu

Location: OHE100D (or tbd)

Syllabus Changes

2025-07-14 none yet.

2025-08-11: correct exam dates

2025-11-10: correct final exam date on page 14.

Catalog Course Description

(Advanced) Computer Networking: Protocol design for computer communication networks, network routing, transport protocols, internetworking.

Prerequisite: CSCI 350 (CSCI 353 or EE 450) and (CSCI 350 or CSCI 402)

Recommended Preparation: C-language programming

Course Description

The goal of the course is to introduce students to graduate-level computer networking principals, including network architecture, routing, transport prototocols, wireless networking, traffic modeling, cloud computing, data centers, content-delivery networks, network security, and privacy. The course includes a substantial class project, which will involve implementation of a network protocol or system (in CSci551) or work on a student-specific research project (in CSci651).

This course will teach computer science and EE students about about protocol design, enablign students to:

- Select appropriate network protocols for different tasks
- Design new newtork protocols
- Reason about network systems in the wide area, cloud, and data center
- Weigh trade-offs in network security, privacy, and performance

Technological Proficiency and Hardware/Software Required

All students are expected to be familiary with C programming (or similar systems-level languages such as C++ or Go).

Prerequisites:

- undergraduate networking, such as CSCI 350, CSCI 353, or EE 450
- undergraduate operating systems, such as CSCI 350 or CSCI 402

Required Readings and Supplementary Materials

The primary required readings will be papers provided on the class website.

Grading Breakdown

midterm(s)	25%
final	30%
homework	10%
projects	30%
class participation	5%

Course Evaluations

Course evaluation occurs at the end of the semester university-wide. It is an important review of students' experience in the class. The process and intent of the end-of-semester evaluation should be provided. In addition, a mid-semester evaluation is recommended practice for early course correction. You may choose to contact CET for support in creating a mid-semester evaluation.

Course Schedule

Class meets Monday/Wednesday, 10am–11:50am, beginning Monday, 2025-08-25 and ending Wednesday, 2025-12-03.

We will have **two short midterms** at 10am Wednesday 2025-09-24 and 10am Wednesday 2025-10-29, and a **final exam** on Monday 2025-12-15, from 8:00 to 10:00am.

All students are expected to confirm they can make both the midterm and final exams—we do not offer alternative dates.

Two imporant things about this schedule:

1. I topics may shift some over the semester, and I will add some papers. Any changes will be announced on the Moodle.
2. We often run slightly behind this schedule, sometimes for several weeks. I encourage students to read following the schedule. All assignments that depend on the shedule *will follow this schedule* regardless of where we are in class lectures.

Office Hours: Office hours are Mondays, 1:30pm to 3-m in GCS LL2 (room to be confirmed). The professors' campus office this semester is GCS 302F, but most students don't have direct access–e-mail me to schedule a meeting time and I can come get you.

Week 1: Reference and Background

(Aug. 25 and Aug. 27)

Project A assigned August 25, due September 10.

Primary: Tips for reading papers: [Hanson99a]

P1. [Hanson99a] Michael J. Hanson. Efficient reading of papers in science. Brochure of unknown origin, revised 1999 by Dylan J. McNamee, 1989.

What to look for in systems papers: [Levin83a]

P2. [Levin83a] Roy Levin and David D. Redell. An evaluation of the ninth SOSP submissions, or how (and how not) to write a good systems paper. *ACM Operating Systems Review*, 17(3):35–40, July 1983.

Finding and judging new ideas: [Heilmeier92a]

P3. [Heilmeier92a] George H. Heilmeier. Some reflections on innovation and invention. *The Bridge*, 22:12–16, Winter 1992.

No paper, but we will review and discuss: General networking, network addressing, data marshalling, packet formats and encoding.

Supplemental:
Another viewpoint of paper reading [Jamin03a]

S1. [Jamin03a] Sugih Jamin. Paper reading and writing check lists. web page `http://irl.eecs.umich.edu/jamin/courses/eecs589/papers/checklist.html`, November 2003.

Week 2: Design Principles of Networking

(Sep. 1 and Sep. 3)

No class Sept. 2 due to Labor Day, a USC holiday.

Primary: The Internet architecture: [Clark88a]

P4. [Clark88a] David D. Clark. The design philosophy of the DARPA Internet protocols. In *Proceedings of the 1988 Symposium on Communications Architectures and Protocols*, pages 106–114. ACM, August 1988.

Naming: [Saltzer82a]

P5. [Saltzer82a] Jermome H. Saltzer. On the naming and binding of network destinations. In *International Symposium on Local Computer Networks*, pages 311–317, April 1982.

The end-to-end argument: [Saltzer81a]

P6. [Saltzer81a] J. H. Saltzer, D. P. Reed, and D. D. Clark. End-to-end arguments in system design. *Proceedings of the 2nd International Conference on Distributed Computing Systems*, pages 509–512, April 1981.

Supplemental:
How "tussles" affect network architecture: [Clark02a]

S2. [Clark02a] David D. Clark, John Wroclawski, Karen Sollins, and Robert Braden. Tussle in cyberspace: Defining tomorrow's internet. In *Proceedings of the ACM SIGCOMM Conference*, pages 347–356, Pittsburgh, PA, USA, August 2002. ACM.

Week 3: Transport protocols and Congestion Control

(Sep. 8 and Sep. 10):

Project B assigned Sep. 9, due October 15.

Primary:

TCP and congestion control: [Jacobson88a]

P7. [Jacobson88a] Van Jacobson. Congestion avoidance and control. In *Proceedings of the ACM SIGCOMM Conference*, pages 314–329, Stanford, California, USA, August 1988. ACM.

Congestion control from first principles: [Ramakrishnan90a]

P8. **[Ramakrishnan90a]** K. K. Ramakrishnan and Raj Jain. A binary feedback scheme for congestion avoidance in computer networks. *ACM Transactions on Computer Systems*, 8(2):158–181, May 1990.

Bottleneck Bandwidth and Round-trip TCP [Cardwell17a]

P9. **[Cardwell17a]** Neal Cardwell, Yuchung Cheng, C. Stephen Gunn, Soheil Hassas Yeganeh, and Van Jacobson. BBR: Congestion-based congestion control. *Communications of the ACM*, 60(2):58–66, February 2017.

Supplemental:

An early academic paper on TCP, prompting the 2004 Turning Award for its authors: [Cerf74a]

S3. **[Cerf74a]** Vint Cerf and Robert Kahn. A protocol for packet network interconnection. *IEEE Transactions on Communications*, COM-22(5):637–648, May 1974.

Modeling TCP: [Padhye98a]

S4. **[Padhye98a]** J. Padhye, V. Firoiu, D. Towsley, and J. Kurose. Modelling TCP throughput: A simple model and its empirical validation. In *Proceedings of the ACM SIGCOMM Conference*, pages 303–314, Vancouver, Canada, September 1998. ACM.

TCP extensions for a datacenter: [Alizadeh10a]

S5. **[Alizadeh10a]** Mohammad Alizadeh, Albert Greenberg, David A. Maltz, Jitendra Padhye, Parveen Patel, Balaji Prabhakar, Sudipta Sengupta, and Murari Sridharan. Data center TCP (DCTCP). In *Proceedings of the ACM SIGCOMM Conference*, New Delhi, India, August 2010. ACM.

Week 4: Routing and Topology

(Sep. 15 and Sep. 17)

Primary:

Review of unicast and distance vector routing. (Will use class notes, plus please review your EE450 work.)

BGP introduction: [Caesar05a]

P10. **[Caesar05a]** Matthew Caesar and Jennifer Rexford. BGP routing policies in ISP networks. *IEEE Network Magazine*, 19(6):5–11, November 2005.

Routing stability and oscillation (plus a taste of queueing theory): [Shaikh00a]

P11. **[Shaikh00a]** Aman Shaikh, Lampros Kalampoukas, Rohit Dube, and Anujan Varma. Routing stability in congested networks: Experimentation and analysis. In *Proceedings of the ACM SIGCOMM Conference*, pages 163–174, Stockholm, Sweeden, August 2000. ACM.

Routing security:

[Goldberg14a]

P12. **[Goldberg14a]** Sharon Goldberg. Why is it taking so long to secure Internet routing? *Communications of the ACM*, 57(10):56–63, October 2014.

Supplemental:
Additional background about BGP: [Balakrishnan08a]

S6. **[Balakrishnan08a]** Hari Balakrishnan. Interdomain internet routing. web page `http://stellar.mit.edu/S/course/6/sp08/6.829/courseMaterial/topics/topic4/lectureNotes/noname/noname`, Spring 2008.

Synchronization problems in routing (but also applies much wider): [Floyd94b]

S7. **[Floyd94b]** S. Floyd and V. Jacobson. The synchronization of periodic routing messages. *ACM/IEEE Transactions on Networking*, 2(2):122–136, April 1994.

Routing hierarchy and policy: [Gao01b]

S8. **[Gao01b]** Lixin Gao. On inferring autonomous system relationships in the Internet. *ACM/IEEE Transactions on Networking*, 9(6):733–745, December 2001.

Google's peering approach (Espresso) [Yap17a]

S9. **[Yap17a]** Kok-Kiong Yap, Murtaza Motiwala, Jeremy Rahe, Steve Padgett, Matthew Holliman, Gary Baldus, Marcus Hines, Taeeun Kim, Ashok Narayanan, Ankur Jain, Victor Lin, Colin Rice, Brian Rogan, Arjun Singh, Bert Tanaka, Manish Verma, Puneet Sood, Mukarram Tariq, Matt Tierney, Dzevad Trumic, Vytautas Valancius, Calvin Ying, Mahesh Kallahalla, Bikash Koley, and Amin Vahdat. Taking the edge off with Espresso: Scale, reliability and programmability for global Internet peering. In *Proceedings of the ACM SIGCOMM Conference*, pages 432–445, Los Angeles, CA, USA, August 2017. ACM.

Week 5: Network Measurement and Topoogy

(Sep. 22 and Sep. 24)

Short Midterm 1 will be the first 35 minutes of Wednesday September 24.

Network measurement: topology, outages, and traffic

Primary:

Network topology: [Oliveira08a]

P13. **[Oliveira08a]** Ricardo V. Oliveira, Dan Pei, Walter Willinger, Beichuan Zhang, and Lixia Zhang. In search of the elusive ground truth: the Internet's AS-level connectivity structure. In *Proceedings of the ACM SIGMETRICS*, pages 217–228. ACM, June 2008.

Edge-network outages: [Quan13c]

P14. **[Quan13c]** Lin Quan, John Heidemann, and Yuri Pradkin. Trinocular: Understanding Internet reliability through adaptive probing. In *Proceedings of the ACM SIGCOMM Conference*, pages 255–266, Hong Kong, China, August 2013. ACM.

This is your network on Covid: [Boettger20a]

P15. **[Boettger20a]** Timm Böttger, Ghida Ibrahim, and Ben Vallis. How the Internet reacted to Covid-19—a perspective from Facebook's edge network. In *Proceedings of the ACM Internet Measurement Conference*, pages 34–41, Pittsburgh, PA, USA, October 2020. ACM.

Supplemental:
Congestion in the network: [Dhamdhere18a]

S10. [**Dhamdhere18a**] Amogh Dhamdhere, David D. Clark, Alexander Gamero-Garrido, Matthew Luckie, Ricky K. P. Mok, Gautam Akiwate, Kabir Gogia, Vaibhav Bajpai, Alex C. Snoeren, and kc claffy. Inferring persistent interdomain congestion. In *Proceedings of the ACM SIGCOMM Conference*, pages 1–15, Budapest, Hungary, August 2018. ACM.

Routing outages, results, and causes: [Wang06b]

S11. [**Wang06b**] Feng Wang, Zhuoqing Morley Mao, Jia Wang, Lixin Gao, and Randy Bush. A measurement study on the impact of routing events on end-to-end Internet path performance. In *Proceedings of the ACM SIGCOMM Conference*, pages 375–386, Pisa, Italy, August 2006. ACM.

Flow-level rerouting with Proactive ReRoute at Google: [Wetherall23a]

S12. [**Wetherall23a**] David Wetherall, Abdul Kabbani, Van Jacobson, Jim Winget, Yuchung Cheng, Morrey, Charles B., Uma Moravapalle, Phillipa Gill, Steven Knight, and Amin Vahdat. Improving network availability with protective ReRoute. In *Proceedings of the ACM SIGCOMM Conference*, pages 684–695, New York, NY, USA, September 2023. ACM.

Week 6: Active Queue Management

(Sep. 29 and Oct. 1):

Primary: Active queue management, such as fair queueing: [Demers89a]

P16. [**Demers89a**] Alan Demers, Srinivasan Keshav, and Scott Shenker. Analysis and simulation of a fair queueing algorithm. In *Proceedings of the ACM SIGCOMM Conference*, pages 1–12, Austin, Texas, September 1989. ACM.

Early drop with CoDel: [Nichols12a]

P17. [**Nichols12a**] Kathleen Nichols and Van Jacobson. Controlling queue delay. *Communications of the ACM*, 55(7):42–50, July 2012.

Week 7: Active Queue Management and a Return to Transport Protocols

(Oct. 6 and Oct. 8)

Primary: XCP and non-TCP congestion control: [Katabi02a]

P18. [**Katabi02a**] Dina Katabi, Mark Handley, and Charlie Rohrs. Congestion control for high bandwidth-delay product networks. In *Proceedings of the ACM SIGCOMM Conference*, pages 89–102, Pittsburgh, PA, USA, August 2002. ACM.

NEW Congestion control by exhaustive computer search: [Winstein13a]

P19. [**Winstein13a**] Keith Winstein and Hari Balakrishnan. TCP ex machina: Computer-generated congestion control. In *Proceedings of the ACM SIGCOMM Conference*, pages 123–134, Hong Kong, China, August 2013. ACM.

Supplemental:
QUIC, an replacement for TCP that avoids head-of-line blocking [Langley17a]

S13. **[Langley17a]** Adam Langley, Alistair Riddoch, Alyssa Wilk, Antonio Vicente, Charles Krasic, Dan Zhang, Fan Yang, Fedor Kouranov, Ian Swett, Janardhan Iyengar, Jeff Bailey, Jeremy Dorfman, Jim Roskind, Joanna Kulik, Patrik Westin, Raman Tenneti, Robbie Shade, Ryan Hamilton, Victor Vasiliev, Wan-Teh Chang, and Zhongyi Shi. The QUIC transport protocol: Design and internet-scale deployment. In *Proceedings of the ACM SIGCOMM Conference*, pages 183–196, Los Angeles, CA, USA, August 2017. ACM.

Week 8: Wireless and Mobile Networking

(Oct. 13 and Oct. 15)

Project C assigned Oct. 14, due Nov. 19.

Primary:

Non-IP routing in sensor networks: [Intanagonwiwat00a]

P20. **[Intanagonwiwat00a]** Chalermek Intanagonwiwat, Ramesh Govindan, and Deborah Estrin. Directed diffusion: A scalable and robust communication paradigm for sensor networks. In *Proceedings of the ACM International Conference on Mobile Computing and Networking*, pages 56–67, Boston, MA, USA, August 2000. ACM.

Mobile (cellular) networks: 4G LTE performance: [Huang13a]

P21. **[Huang13a]** Junxian Huang, Feng Qian, Yihua Guo, Yuanyuan Zhou, Qiang Xu, and Z. Morley Mao. An in-depth study of LTE: Effect of network protocol and application behavior on performance. In *Proceedings of the ACM SIGCOMM Conference*, pages 363–374, Hong Kong, China, Aug 2013. ACM.

5G mobile networks: [Narayanan21a]

P22. **[Narayanan21a]** Arvind Narayanan, Xumiao Zhang, Ruiyang Zhu, Ahmad Hassan, Shuowei Jin, Xiao Zhu, Xiaoxuan Zhang, Denis Rybkin, Zhengxuan Yang, Z. Morley Mao, Feng Qian, and Zhi-Li Zhang. A variegated look at 5G in the wild: Performance, power, and QoE implications. In *Proceedings of the ACM SIGCOMM Conference*, pages 610–626, Virtual, August 2021. ACM.

Supplemental:
MAC protocols: [Bharghavan94a]

S14. **[Bharghavan94a]** Vaduvur Bharghavan, Alan Demers, Scott Shenker, and Lixia Zhang. MACAW: A media access protocol for wireless LANs. In *Proceedings of the ACM SIGCOMM Conference*, pages 212–225, London, UK, September 1994. ACM.

More about 5G performance: [Hassan22a]

S15. **[Hassan22a]** Ahmad Hassan, Arvind Narayanan, Anlan Zhang, Wei Ye, Ruiyang Zhu, Shuowei Jin, Jason Carpenter, Z. Morley Mao, Feng Qian, and Zhi-Li Zhang. Vivisecting mobility management in 5G cellular networks. In *Proceedings of the ACM SIGCOMM Conference*, pages 86–100, Amsterdam, Netherlands, August 2022. ACM.

Polymorphic radios: [Rostami18a]

S16. **[Rostami18a]** Mohammad Rostami, Jeremy Gummeson, Ali Kiaghadi, and Deepak Ganesan. Polymorphic radios: A new design paradigm for ultra-low power communication. In *Proceedings of the ACM SIGCOMM Conference*, pages 446–460, Budapest, Hungary, August 2018. ACM.

Week 9: Characterizing Network Traffic

(Oct. 20 and Oct. 22)

Primary:

Self-similarity in LAN traffic: [Leland94a]

P23. **[Leland94a]** W.E. Leland, M.S. Taqqu, W. Willinger, and D.V. Wilson. On the self-similar nature of Ethernet traffic (extended version). *ACM/IEEE Transactions on Networking*, 2(1):1–15, February 1994.

And in WAN and web traffic: [Crovella97a]

P24. **[Crovella97a]** Mark E. Crovella and Azer Bestavros. Self-similarity in world wide web traffic: evidence and possible causes. *ACM/IEEE Transactions on Networking*, 5(6):835–846, December 1997.

Changes to the network topology: [Labovitz10c]

P25. **[Labovitz10c]** Craig Labovitz, Scott Iekel-Johnson, Danny McPherson, Jon Oberheide, and Farnam Jahanian. Internet inter-domain traffic. In *Proceedings of the ACM SIGCOMM Conference*, pages 75–86, New Delhi, India, August 2010. ACM.

Supplemental:
Packet-level network dynamics: [Paxson99b]

S17. **[Paxson99b]** Vern Paxson. End-to-end Internet packet dynamics. *ACM/IEEE Transactions on Networking*, 7(3):277–292, June 1999.

Economics and availability of broadband: [Paul23a]

S18. **[Paul23a]** Udit Paul, Vinothini Gunasekaran, Jiamo Liu, Tejas N. Narechania, Arpit Gupta, and Elizabeth Belding. Decoding the divide: Analyzing disparities in broadband plans offered by major US ISPs. In *Proceedings of the ACM SIGCOMM Conference*, pages 578–591, New York, NY, USA, September 2023. ACM.

Week 10: Cloud Computing and In the Cloud

(Oct. 27 and Oct. 29)

Short Midterm 2 will be the first 35 minutes of Wednesday October 29.

Primary:

While most of the class focuses on protocols that connect things, this class focuses on how one builds data services that can sit at one end of the connection, often the "inside" of the cloud. For more work in this direction, see CSci555 (graduate operating systems) and distributed computing.

Data-parallel processing with map/reduce: [Dean04a]

P26. **[Dean04a]** Jeffrey Dean and Sanjay Ghemawat. MapReduce: Simplified data processing on large clusters. In *Proceedings of the USENIX Symposium on Operating Systems Design and Implementation*, pages 137–150, San Francisco, California, USA, December 2004. USENIX.

Performance out of the cloud: [Dean13a]

P27. **[Dean13a]** Jeffrey Dean and Luiz André Barroso. The tail at scale. *Communications of the ACM*, 56(2):74–80, February 2013.

Running an enterprise network and the start of SDN (Ethane, a parent of OpenFlow): [Casado09a]

P28. [Casado09a] Martin Casado, Michael J. Freedman, Justin Pettit, Jianying Luo, Natasha Gude, Nick McKeown, and Scott Shenker. Rethinking enterprise network control. *ACM/IEEE Transactions on Networking*, 17(4):1270–1283, August 2009.

([Casado09a] belongs in the next week, but is pulled here to balance the workload.)

Supplemental: Early large-scale services [Fox97a]

S19. [Fox97a] Armando Fox, Steven D. Gribble, Yatin Chawathe, Eric A. Brewer, and Paul Gauthier. Cluster-based scalable network services. In *Proceedings of the 16th Symposium on Operating Systems Principles*, pages 78–91, St. Malo, France, October 1997. ACM.

SDN in the cloud: [Ferguson21a]

S20. [Ferguson21a] Andrew D. Ferguson, Steve Gribble, Chi-Yao Hong, Charles Killian, Waqar Mohsin, Henrik Muehe, Joon Ong, Leon Poutievski, Arjun Singh, Lorenzo Vicisano, Richard Alimi, Shawn Shuoshuo Chen, Mike Conley, Subhasree Mandal, Karthik Nagaraj, Kondapa Naidu Bollineni, Min Zhu Amr Sabaa, Shidong Zhang, and Amin Vahdat. Orion: Google's software-defined networking control plane. In *Proceedings of the 18th USENIX Symposium on Network Systems Design and Implementation*, pages 83–98, Virtual Location, April 2021. USENIX.

Week 11: Data Center Networks and Software Defined Networking

(Nov. 3 and Nov. 5)

P4, generalzing OpenFlow: [Bosshart14a]

P29. [Bosshart14a] Pat Bosshart, Dan Daly, Glen Gibb, Martin Izzard, Nick McKeown, Jennifer Rexford, Cole Schlesinger, Dan Talayco, Amin Vahdat, George Varghese, and David Walker. P4: Programming protocol-independent packet processors. *ACM Computer Communication Review*, 44(3):88–95, July 2014.

Optimizing a datacenter network: [Greenberg09a]

P30. [Greenberg09a] Albert Greenberg, James R. Hamilton, Navendu Jain, Srikanth Kandula, Changhoon Kim, Parantap Lahiri, David A. Maltz, and Parveen Pat. VL2: A scalable and flexible data center network. In *Proceedings of the ACM SIGCOMM Conference*, pages 51–62, Barcelona, Spain, August 2009. ACM.

Getting the data out of the datacenter: [Schlinker17a]

P31. [Schlinker17a] Brandon Schlinker, Hyojeong Kim, Timothy Cui, Ethan Katz-Bassett, Harsha V. Madhyastha, Italo Cunha, James Quinn, Saif Hasan, Petr Lapukhov, and Hongyi Zeng. Engineering egress with Edge Fabric: Steering oceans of content to the world. In *Proceedings of the ACM SIGCOMM Conference*, pages 418–431, Los Angeles, CA, USA, August 2017. ACM.

Supplemental:
A review of 10 years of Google datacenter topologies: [Singh15a]

S21. [Singh15a] Arjun Singh, Joon Ong, Amit Agarwal, Glen Anderson, Ashby Armistead, Roy Bannon, Seb Boving, Gaurav Desai, Bob Felderman, Paulie Germano, Anand Kanagala, Jeff Provost, Jason Simmons, Eiichi Tanda, Jim Wanderer, Urs Hoelzle, Stephen Stuart, and Amin Vahdat. Jupiter rising: A decade of Clos topologies and centralized control in Google's datacenter network. In *Proceedings of the ACM SIGCOMM Conference*, page to appear, London, UK, August 2015. ACM.

Facebook's data center [Roy15a]

S22. [Roy15a] Arjun Roy, Hongyi Zeng, Jasmeet Bagga, George Porter, and Alex C. Snoeren. Inside the social network's (datacenter) network. In *Proceedings of the ACM SIGCOMM Conference*, pages 123–137, London, UK, August 2015. ACM.

Network virtualization in datacenters: [Koponen14a]

S23. [Koponen14a] Teemu Koponen, Keith Amidon, Peter Balland, Martín Casado, Anupam Chanda, Bryan Fulton, Igor Ganichev, Jesse Gross, Natasha Gude, Paul Ingram, Ethan Jackson, Andrew Lambeth, Romain Lenglet, Shih-Hao Li, Amar Padmanabhan, Justin Pettit, Ben Pfaff, Rajiv Ramanathan, Scott Shenker, Alan Shieh, Jeremy Stribling, Pankaj Thakkar, Dan Wendlandt, Alexander Yip, and Ronghua Zhang. Network virtualization in multi-tenant datacenters. In *Proceedings of the USENIX Symposium on Network Systems Design and Implementation*, pages 203–216, Seattle, WA, USA, April 2014. USENIX.

Week 12: Network Architecture Past and Future

(Nov. 10 and Nov. 12)

Primary:

Google's use of Software Defined Networking for traffic engineering: [Jain13a]

P32. [Jain13a] Sushant Jain, Alok Kumar, Joon Ong Subhasree Mandal, Leon Poutievski, Arjun Singh, Subbaiah Venkata, Jim Wanderer, Junlan Zhou, Jonathan Zolla Min Zhu, Urs Hölzle, Stephen Stuart, and Amin Vahdat. B4: Experience with a globally-deployed software defined WAN. In *Proceedings of the ACM SIGCOMM Conference*, pages 3–14, Hong Kong, China, August 2013. ACM.

Information-centric networking: [Jacobson12a]

P33. [Jacobson12a] Van Jacobson, Diana K. Smetters, James D. Thornton, Michael Plass, Nick Briggs, and Rebecca Braynard. Networking named content. *Communications of the ACM*, 55(1):117–124, January 2012.

Spam and anti-spam: [Levchenko11a]

P34. [Levchenko11a] Kirill Levchenko, Andreas Pitsillidis, Neha Chachra, Brandon Enright, Márk Félegyházi, Chris Grier, Tristan Halvorson, Chris Kanich, Christian Kreibich, He Liu, Damon McCoy, Nicholas Weaver, Vern Paxson, Geoffrey M. Voelker, and Stefan Savage. Click trajectories: End-to-end analysis of the spam value chain. In *Proceedings of the IEEE Symposium on Security and Privacy*, pages 431–446, Oakland, CA, USA, May 2011. IEEE.

([Levchekno11a] really belongs in the security section next week, but it's pulled back one week to balance the workload.)

Supplemental:

A classic paper on quality of service and admission control, plus max/min fairness and fair queueueing: [Shenker95a]

S24. [Shenker95a] Scott Shenker. Fundamental design issues for the future Internet. *IEEE Journal of Selected Areas in Communication*, 13(7):1176–1188, September 1995.

Modern congestion control and streaming video: [Akhtar18a]

S25. [Akhtar18a] Zahaib Akhtar, Yun Seong Nam, Ramesh Govindan, Sanjay Rao, Jessica Chen, Ethan Katz Bassett, Bruno Martins Ribeiro, and Hui Zhang Jibin Zhan. Oboe: Auto-tuning video ABR algorithms to network conditions. In *Proceedings of the ACM SIGCOMM Conference*, pages 44–59, Budapest, Hungary, August 2018. ACM.

Traffic engineering: [Hong13a]

S26. **[Hong13a]** Chi-Yao Hong, Srikanth Kandula, Ratul Mahajan, Ming Zhang, Vijay Gill, Mohan Nanduri, and Roger Wattenhofer. Achieving high utilization with software-driven WAN. In *Proceedings of the ACM SIGCOMM Conference*, pages 15–26, Hong Kong, China, August 2013. ACM.

Week 13: Network Security

(Nov. 17 and Nov. 19)

Primary:

TLS interception: [Raman20a]

P35. **[Raman20a]** Ram Sundara Raman, Leonid Evdokimov, Eric Wurstrow, J. Alex Halderman, and Roya Ensafi. Investigating large scale HTTPS interception in Kazakhstan. In *Proceedings of the ACM Internet Measurement Conference*, pages 125–132, Pittsburgh, PA, USA, October 2020. ACM.

Onion routing (TOR): [Dingledine04a]

P36. **[Dingledine04a]** Roger Dingledine, Nick Mathewson, and Paul Syverson. Tor: The second-generation onion router. In *Proceedings of the 13th USENIX Security Symposium*, pages 303–320, San Diego, CA, USA, August 2004. USENIX.

Supplemental:
Denial of service attacks: [Hussain03b]

S27. **[Hussain03b]** Alefiya Hussain, John Heidemann, and Christos Papadopoulos. A framework for classifying denial of service attacks. In *Proceedings of the ACM SIGCOMM Conference*, pages 99–110, Karlsruhe, Germany, August 2003. ACM.

Worm propagation: [Staniford02a]

S28. **[Staniford02a]** Stuart Staniford, Vern Paxson, and Nicholas Weaver. How to 0wn the Internet in your spare time. *Proceedings of the 11th USENIX Security Symposium*, pages 149–167, August 2002.

Multi-party TLS: [Naylor15a]

S29. **[Naylor15a]** David Naylor, Kyle Schomp, Matteo Varvello, Ilias Leontiadis, Jeremy Blackburn, Diego Lopez, Konstantina Papagiannaki, Pablo Rodriguez Rodriguez, and Peter Steenkiste. Multi-context TLS (mcTLS): Enabling secure in-network functionality in TLS. In *Proceedings of the ACM SIGCOMM Conference*, page to appear, London, UK, August 2015. ACM.

(Note that, in this class, we intentionally do not do the cryptographic side of network security. There is coverage of that material in CSci555, Graduate Operating Systems, and most of CSci530, Security Systems, is about that.)

Unfortunately there is not time to talk about security and network protocols in CSci551. CSci555 provides a good coverage of security from an operating systems perspective; see the papers by Voydock and Kent and Needham and Schroder there.

Week 14: Peer-to-peer and Content Delivery Networks

(Nov. 24 and Nov. 26), but *no class Nov. 26* due to the Thanksgiving holiday

The professor will be out on travel Monday 2025-11-24; we expect to pre-record that lecture the week before, probably on Friday.

Primary:

Efficient peer-to-peer storage: [Stoica00a]

P37. **[Stoica00a]** Ion Stoica, Robert Morris, David Karger, M. Frans Kaashoek, and Hari Balakrishnan. Chord: A scalable peer-to-peer lookup service for Internet applications. In *Proceedings of the ACM SIGCOMM Conference*, pages 149–160, Stockholm, Sweden, September 2000. ACM.

Microsoft Bing's anycast CDN: [Calder15a]

P38. **[Calder15a]** Matt Calder, Ashley Flavel, Ethan Katz-Bassett, Ratul Mahajan, and Jitendra Padhye. Analyzing the performance of an anycast CDN. In *Proceedings of the ACM Internet Measurement Conference*, pages 531–537, Tokyo, Japan, October 2015. ACM.

Latency in and out of the cloud: [Jin19a]

P39. **[Jin19a]** Yuchen Jin, Sundararajan Renganathan, Ganesh Ananthanarayanan, Junchen Jiang, Venkata N. Padmanabhan, Manuel Schroder, Matt Calder, and Arvind Krishnamurthy. Zooming in on wide-area latencies to a global cloud provider. In *Proceedings of the ACM SIGCOMM Conference*, pages 104–116, Beijing, China, August 2019. ACM.

Supplemental:
Akamai, a modern CDN: [Schomp20a]

S30. **[Schomp20a]** Kyle Schomp, Onkar Bhardwaj, Eymen Kurdoglu, Mashooq Muhaimen, and Ramesh K. Sitaraman. Akamai DNS: Providing authoritative answers to the world's queries. In *Proceedings of the ACM SIGCOMM Conference*, pages 465–478, Virtual, July 2020. ACM.

Freenet and anonymous peer-to-peer file sharing: [Clarke02a]

S31. **[Clarke02a]** Ian Clarke, Theodore W. Hong, Scott G. Miller, Oskar Sandberg, and Brandon Wiley. Protecting free expression online with Freenet. *IEEE Internet Computing*, 6(1):40–49, February 2002.

Privacy built over BitTorrent in OneSwarm: [Isdal10a]

S32. **[Isdal10a]** Tomas Isdal, Michael Piatek, Arvind Krishnamurthy, and Thomas Anderson. Privacy-preserving P2P data sharing with OneSwarm. In *Proceedings of the ACM SIGCOMM Conference*, pages 111–122, New Delhi, India, August 2010. ACM.

Week 15: Privacy and Ethics

(Dec. 1 and Dec. 3)

Ethics and network research: [Dittrich11a]

P40. **[Dittrich11a]** David Dittrich and Erin Kenneally (editors). The Menlo report: Ethical principles guiding information and communication technology research. Technical report, United States Department of Homeland Security, September 2011.

Supplemental:

Network data collection and differential privacy: [McSherry10a]

S33. [McSherry10a] Frank McSherry and Ratul Mahajan. Differentially-private network trace analysis. In *Proceedings of the ACM SIGCOMM Conference*, pages 123–134, New Delhi, India, August 2010. ACM.

Finals Week

The **final exam** is on 2 0 2 5 - 1 2 - 1 0 Monday 2025-12-15, from 8:00 to 10:00am.

Academic Integrity

USC's Academic Integrity Policy

The University of Southern California is foremost a learning community committed to fostering successful scholars and researchers dedicated to the pursuit of knowledge and the transmission of ideas. Academic misconduct—which includes any act of dishonesty in the production or submission of academic work (either in draft or final form)—is in contrast to the university's mission to educate students through a broad array of academic, professional, and extracurricular programs.

This course will follow the expectations for academic integrity as stated in the USC Student Handbook (https://policy.usc.edu/studenthandbook/). All students are expected to submit assignments that are their own original work and prepared specifically for this course and section in this academic term. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s). Students suspected of engaging in academic misconduct will be reported to the Office of Academic Integrity.

Other violations of academic misconduct include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

Academic dishonesty has a far-reaching impact and is considered a serious offense against the university. Violations will result in a grade penalty, such as a failing grade on the assignment or in the course, and disciplinary action from the university itself, such as suspension or even expulsion.

For more information about academic integrity see the student handbook (https://policy.usc.edu/studenthandbook/) or the Office of Academic Integrity's website (https://academicintegrity.usc.edu/), and university policies on Research and Scholarship Misconduct (https://policy.usc.edu/research-and-scholarship-mi

Please ask the instructor [and/or TA(s)] if you are unsure about what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

Use of Generative AI in this Course

Generative AI is not permitted: Since creating, analytical, and critical thinking skills are part of the learning outcomes of this course, all assignments should be prepared by the student working individually or in groups as described on each assignment. Students may not have another person or entity complete any portion of the assignment. Developing strong competencies in these areas will prepare you for a competitive workplace. Therefore, using AI-generated tools is prohibited in this course, will be identified as plagiarism, and will be reported to the Office of Academic Integrity.

Class Recordings and Course Content Distribution

You may not record this class without the express permission of the instructor and all other students in the class. Distribution of any notes, recordings, exams, or other materials from a university class or lectures—other than for individual or class group study—is prohibited without the express permission of the instructor; violations will be considered an intentional act to facilitate or enable academic dishonesty and reported to the university

Course Content Distribution and Synchronous Session Recordings Policies

USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. (Living our Unifying Values: The USC Student Handbook, page 13, https://policy.usc.edu/studenthandbook/).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relation to the class, whether obtained in class, via email, on the internet, or via any other media. Distributing course material without the instructor's permission will be presumed to be an intentional act to facilitate or enable academic dishonestly and is strictly prohibited. (Living our Unifying Values: The USC Student Handbook, page 13, https://policy.usc.edu/studenthandbook/)

Statement on University Academic and Support Systems

Students and Disability Accommodations

USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Student Financial Aid and Satisfactory Academic Progress

To be eligible for certain kinds of financial aid, students are required to maintain Satisfactory Academic Progress (SAP) toward their degree objectives. Visit the Financial Aid Office webpage for undergraduate- and graduate-level SAP eligibility requirements and the appeals process.

Support Systems

Counseling and Mental Health: (213) 740–9355: 24/7 on call.

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

988 Suicide and Crisis Lifeline: 988 for both calls and text messages: 24/7 on call.

The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline consists of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273–8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

Relationship and Sexual Violence Prevention Services (RSVP): (213) 740-9355(WELL): 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender- and power- based harm (including sexual assault, intimate partner violence, and stalking).

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX): (213) 740-5086

Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment: (213) 740-2500

Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

The Office of Student Accessibility Services (OSAS): (213) 740-0776

OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

USC Campus Support and Intervention: (213) 740-0411

Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity, Equity and Inclusion: (213) 740-2101

Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency UPC: (213) 740-4321, HSC: (323) 442-1000: 24/7 on call

Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety: UPC: (213) 740-6000, HSC: (323) 442-1200: 24/7 on call

Non-emergency assistance or information.

Office of the Ombuds: (213) 821-9556 (UPC) / (323-442-0382 (HSC)

A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

Occupational Therapy Faculty Practice: (323) 442-2850 or otfp@med.usc.edu

Confidential Lifestyle Redesign services for USC students to support health-promoting habits and routines that enhance quality of life and academic performance.